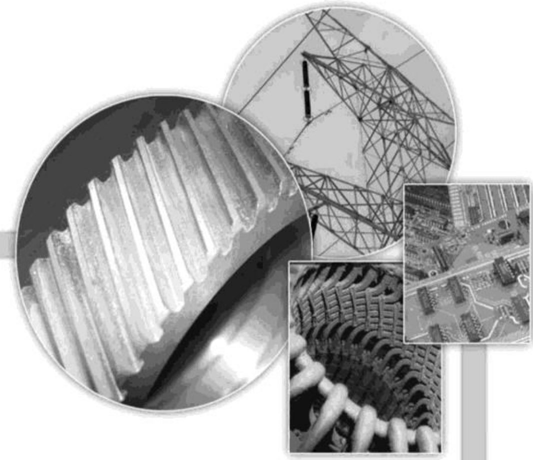


LESSON 4.3

TRANSMISSION LINE PROTECTION USING PILOT WIRE RELAYS

LESSON 4.3 TRANSMISSION LINE PROTECTION USING PILOT WIRE RELAYS

OVERVIEW

In this lesson, principle of pilot wire relaying scheme for Transmission Line Protection is discussed, including Directional Comparison-Blocking, Directional Comparison-Unblocking, Under-Reaching Transfer Trip, Permissive Over-Reaching Transfer Trip and Permissive Under-Reaching Transfer Trip methods. Trainees learn the functions of mutual drainage reactors and neutralizing transformers. The rectifying restraining and operating currents for DC polarized Unit in typical protection scheme are explained.

OBJECTIVES

Upon completion of this lesson, the trainee should be able to:

- Describe differential protection schemes for transmission lines.
- Describe with pilot wire differential protection schemes.
- Draw a typical pilot wire scheme.
- Identify pilot wire monitoring system.
- perform tests on pilot wire test circuit.
- State functions of mutual drainage reactors
- State functions of neutralizing transformers.
- Describe the rectifying restraining and operating currents for polar unit.

INTRODUCTION

The protection principle described in Lessons 1.1 and 1.2, non-pilot protection using Over-Current and Distance Relays, contain a fundamental difficulty. Although clearing the faults at both ends simultaneously, secures the system with more stability, it is not possible to clear a fault from both ends of a transmission line, instantaneously, if the fault is near one end of the transmission line. This is due to the fact that, in detecting a fault using only information obtained at one end, faults near the remote end cannot be cleared without the introduction of sometime delay. As we discussed in Lesson 1.2, there is always an uncertainty at the limits of protective zone. Referring to Fig. 4.3-1, the relay at terminal B trip instantaneously by its first zone and a relay at terminal A use a time delay for second zone or backup tripping to avoid the loss of coordination for a fault at F2.

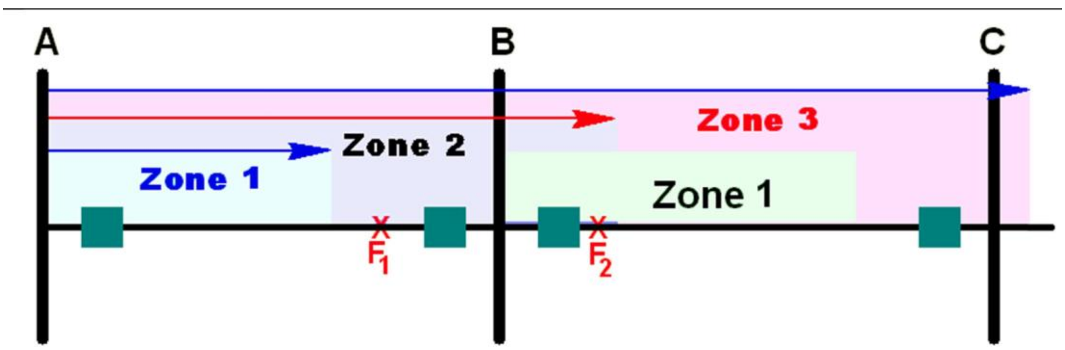


Fig. 4.3-1 Coordination between First and Second Zones

This results in slow clearing for a fault at Fl. The ideal solution would be to use the pilot wire differential protection. This solution is not practical for the majority of transmission lines with long distance involved due to the following:

- For a three phase line, six pilot conductors would be required, one for each phase, one for the neutral and two for the DC positive and negative leads required to trip the circuit breakers.
- For distances beyond **5-10 miles** the cost of the cable alone would make this **impractical**.

- In addition, there could be **"error current"** introduced by CT saturation caused by heavy load.
- Transmission line charging current or **voltage drops** in the cable due to its length and **large secondary currents** during a fault may exist.
- The proximity of the control to the transmission line and its exposure to lightning would require very **high cable insulation**.

All of these factors tend to rule out this method of protection **except for very short lines**.

Pilot protection is an adaptation of the principle of differential relaying to avoid the use of control cable between terminals. The term **"Pilot"** or **"Tele-Protection"** refers to a communication channel between two or more ends of a transmission line to provide instantaneous clearing over 100% of the line.

The types of communication channels used between each end of the line are:

1) Solid metallic connection - Pilot Wire (Communication Cable)
2) Power Line Carrier **(PLC)**
3) Microwave
4) Fiber Optic Cable
5) Radio Frequency (Mobile Radio)

RELAYING SCHEMES

The selection of a communication channel for protection is based upon a great many factors, as follows:

- Cost
- Reliability
- Number of terminals and the distance between them
- Number of channels required for all purposes (not only relaying)
- Frequencies available and the prevailing practice in the power company

In addition to these fundamental considerations, a decision must be made whether the scheme operates in a blocking or tripping mode.

A blocking mode is one in which the presence of a transmitted signal prevent tripping of a circuit breaker. A tripping mode is one in which the signal initiates tripping of a circuit breaker. There are different relaying schemes that accommodate one mode or the other.

The use of blocking signal is preferred if the communication medium is an integral part of the protected line section, such as PLC. In this case the internal fault may prevent or seriously attenuate the signal so that a trip signal would not be received. If a separate transmission medium such as microwave, fiber optic or a pilot cable is used, the integrity of a power line during an internal fault will have no effect on the transmitted signal and a tripping scheme is viable application. In many Extra High Voltage **(EHV)** systems, two primary and secondary protection schemes are used, in which case one may be a tripping and the other may be a blocking system providing protection diversity.

DIRECTIONAL COMPARISON-BLOCKING

The fundamental principle upon which this scheme is based utilizes the fact that, at a given terminal, the direction of a fault either forward or backward, can be easily determined. As discussed in Lesson 1.1, **a directional relay can differentiate between an internal or an external fault.** By transmitting this information to the other end and applying appropriate logic, both ends can determine whether a fault is within the protected line or external to it. For phase faults, a directional or non directional Distance Relay can be used as a fault detector to transmit a blocking signal to prevent the circuit breaker from tripping. Tripping is allowed in the absence of signal in addion to other supervising relay action. A blocking signal is used since the communication path uses the transmission line itself. A directional relay, usually an Admittance type **(Mho)** or Quadrilateral Relay, is used to inhibit the transmitter. For ground faults, either ground Distance Relays similar to the Phase Relays or Directional Ground Over-Current Relays are used. A trip is initiated if the directional relays at both ends have operated and neither end receives a blocking signal. Each receiver receives signals from both the local and remote transmitters.

The logic of the Directional Comparison Scheme is shown in Fig. 4.3-2 and a simplified DC circuit showing the essential contacts to implement this logic is shown in Fig. 4.3-3.

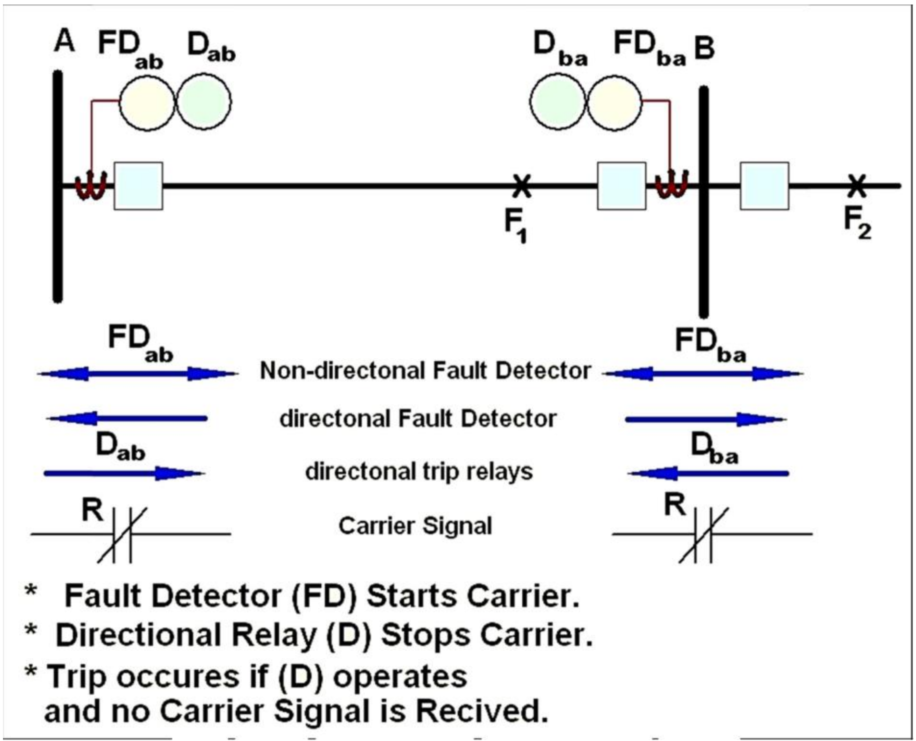


Fig. 4.3-2 Directional Comparison Logic

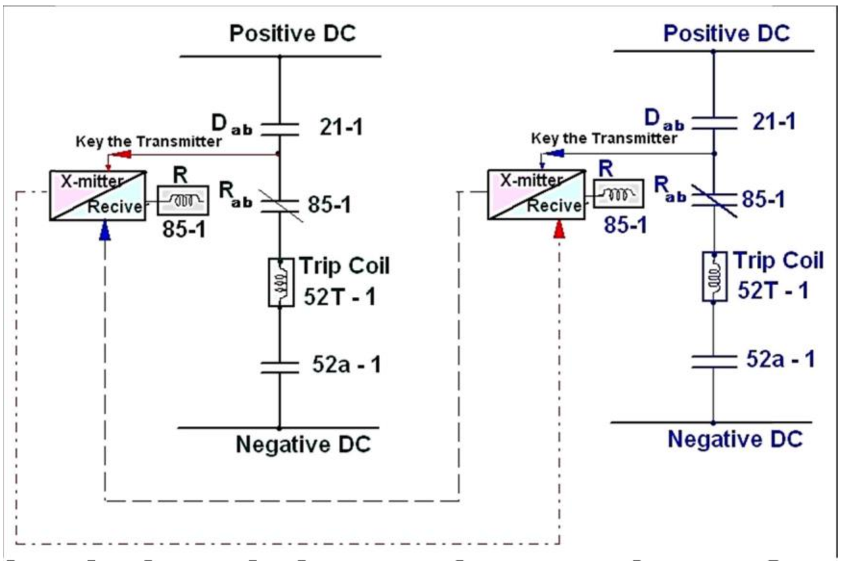


Fig. 4.3-3 DC Circuit for directional Comparison Blocking Scheme

Table 4.3-1 shows the operation of Directional Comparison Blocking Scheme corresponding to Fig. 4.3-2 and Fig. 4.3-3 for internal and external faults.

Assuming an Internal Fault at F1, the tripping relay D_{ab} and D_{ba} will see the fault. If the starting relays FD_{ab} and FD_{ba} are directional, they may or may not see the fault, but Dab and D_{ba} operation will prevent transmission of blocking signal. If they are non-directional, they will start transmission, but being directional relays they will stop it. In either case, since the receiver relay R contacts will be closed due to the absence of a carrier signal and the directional relays have operated, both ends will trip their associated breakers.

Table 4.3-1 Operation of Directional Comparison Blocking Scheme

TYPE OF FAULT	**EVENTS AT TERMINAL A**	**EVENTS AT TERMINAL B**
Internal (F1)	D_{ab} operates. FD_{ab} may or may not operate, but D_{ab} operation prevents transmission of blocking signal. Breaker 1 trips.	D_{ba} operates. FD_{ba} may or may not operate, but D_{ba} operation prevents transmission of blocking signal. Breaker 2 trips.
External (F2)	Dab operates. FD_{ab} does not see fault. Blocking signal received from terminal B keeps R_{ab} (85-1) contact open. Breaker 1 does not trip.	FD_{ba} operates, keying transmitter blocking signal to terminal A keeps R_{ba} (85-1) contact open. D_{ba} does not see fault. Breaker 2 does not trip.

An External Fault at F_2 will result in the operation of relay D_{ab} at breaker 1 but the relay FD_{ab} does not see the fault, if it is directional. If FD_{ab} is non-directional, it will start transmitting a blocking signal to terminal A, but Dab will stop it. At breaker 2, however, FD_{ba} will operate whether it is directional or not, but the tripping relay D_{ba} does not see fault and will not operate to stop transmission. Breaker 1 at terminal A will not trip since it is receiving a blocking signal from terminal B, opening its receiver relay contact R_{ab}. Breaker 2 will not trip for two reasons:

- Breaker 2 is rceiving its own blocking signal.
- Dba Relay has not operated.

DIRECTIONAL COMPARISON-UNBLOCKING

The blocking signal is transmitted only when a fault occurs. If there is any malfunction in the relay or communication equipment such that no signal sent or the receiver relay contact is continuously picked up, the result would be a failure to block during an external fault when the directional tripping relay picks up and a false trip would occur as shown in Fig. 4.3-3. To avoid this, a low energy continuous carrier blocking (Guard) signal is transmitted as a supervisory check on the communication link at normal operation. At internal fault, this signal is removed (unblocked) and the transmitter shifts to unblocking (Trip) frequency with higher transmitted power. The schematic and the simplified DC circuit of the unblocking scheme is shown in Fig. 4.3-4. Under normal conditions, a blocking signal (Guard Input = Hi logic) is sent continuously to inhibit the OR1 gate output and as a result, AND1 and AND2 receive no inputs through path (a), OR2 output being deactivated, receiver relay R is de-energized. During an internal fault, the tripping relay (D) at each end causes the transmitter to shift to the unblocking frequency, removing the input to AND1 to stop the Timer and providing an input to OR2, directly, and then to the receiver relay R, allowing the circuit breaker to trip.

The monitoring logic, path (a), provides protection in the event, there is a loss of a blocking signal without the transmission of an unblocking signal. With no blocking frequency, there is input to OR1 and to AND2. With no blocking signal, there is an input to OR2 through the AND1 and the 150 ms Timer until it times out. This allows the trip during 150 ms after which the circuit locks out. With the directional Comparison Blocking scheme, a failure of communication link will go unnoticed until a false trip occurs during an external fault. With the unblocking scheme, this condition is immediately recognized and the relay is made inoperative. If the carrier goes off during a fault, both schemes are vulnerable to false trips. The reliability and security of directional comparison unblocking systems make them the most attractive of the protective schemes for TL using power line carrier channels. Continuous blocking and channel monitoring avoid over tripping. Only the failure of a channel within 150 ms of an external fault can result in over tripping.

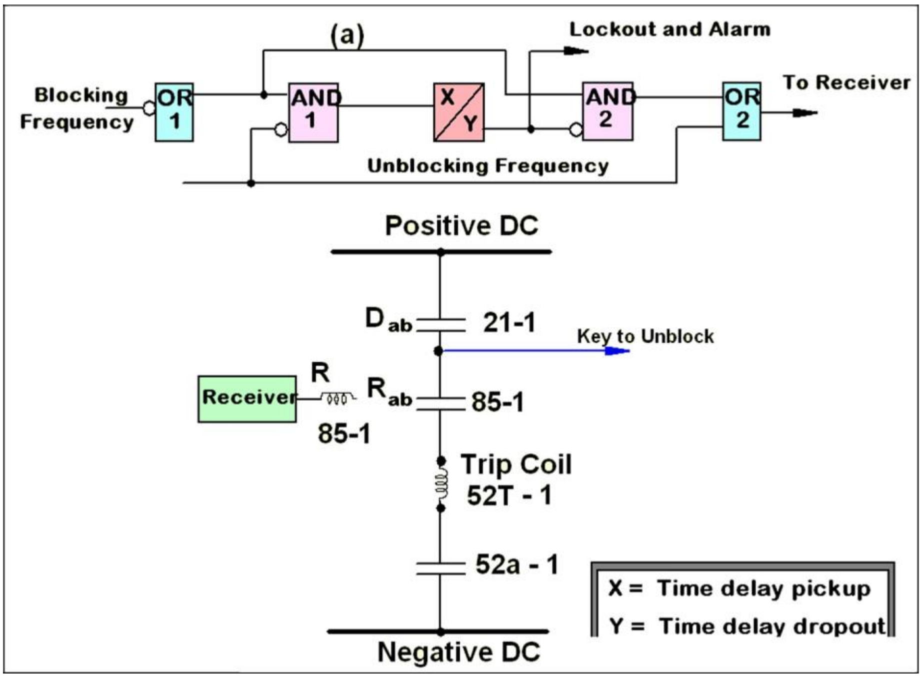


Fig. 4.3-4 Directional Comparison Unblocking

Table 4.3-2 shows the operation of Directional Comparison Unblocking Scheme corresponding Fig. 4.3-4 for internal and external faults.

TYPE OF FAULT	EVENTS AT TERMINAL A	EVENTS AT TERMINAL B
Internal (Fl)	D_{ab} operates. f1 channel shifts to unblock. Loss of block and/or receipt of unblock (f2) operates receiver relay R. Breaker 1 trips.	D_{ba} operates. f2 channel shifts to unblock. Loss of block and/or receipt of unblock (f1) operates receiver relay R. Breaker 2 trips.
External (F2)	D_{ab} operates. f1 channel shifts to unblock. f2 channel continues to block. Breaker 1 does not trip.	Dba does not see fault. Loss of block and/or receipt of unblock (f1) operates receiver relay R. Breaker 2 does not trip.

Table 4.3-2 Operation of Directional Comparison Unblocking Scheme

UNDER-REACHING TRANSFER TRIP

If the transmission line is independent of the power line, a tripping scheme is a viable protection system. There are some advantages of tripping against blocking scheme. Tripping can generally be done faster since there is no need to include coordination time such as shown in Fig. 4.3-3 where the receiver relay must open before the directional relay closes to avoid an incorrect trip on an external fault. In the blocking scheme, the blocking relay must be more sensitive than the tripping relay. This is not always easy to accomplish, particularly, if there is a big difference between the fault contributions at each end. In making this setting, the relay must avoid operating on heavy load or system unbalance. The transfer signal is a frequency shift system as described below. This provides a continuously transmitted guard signal, which must shift to a trip frequency. It is this two-pronged action that should prevent a false trip due to random electrical noise.

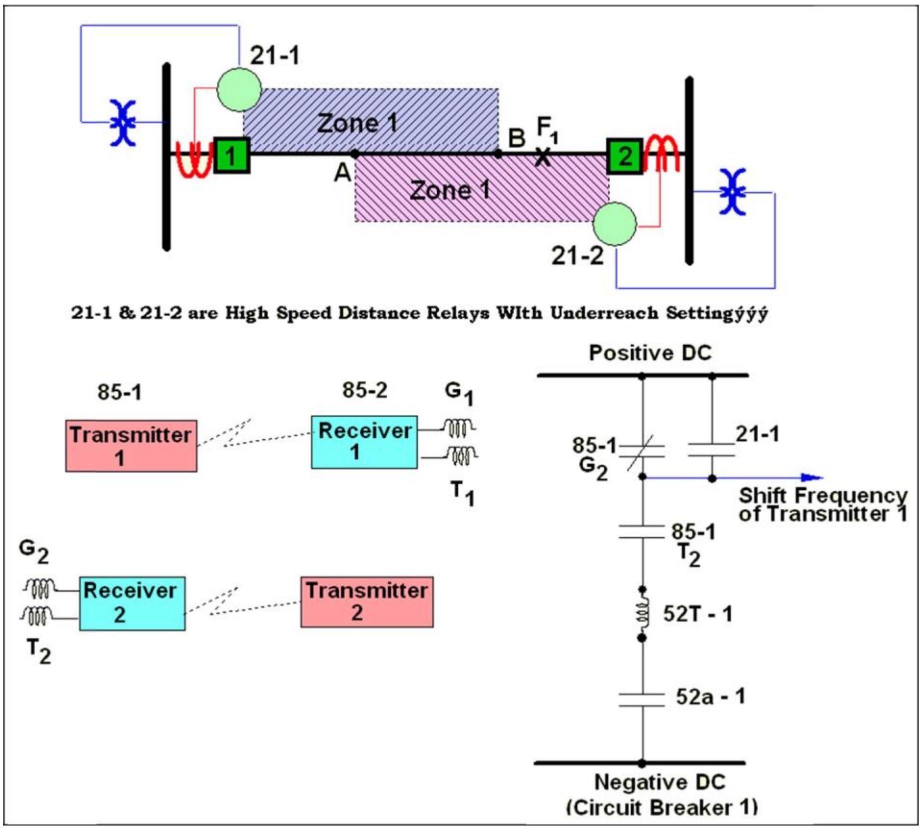


Fig. 4.3-5 One Line and DC Diagram for

Direct Under-Reaching Transfer Trip (DUTT)

The guard frequency must stop and the trip frequency must be received, allowing their respective contacts to close. The continuous guard frequency also monitors the communication channel similar to the directional comparison unblocking scheme. Fig. 4.3-5 shows the schematic and the DC circuit of circuit breaker 1 of a Direct Under-Reaching Transfer Tripping (DUTT) scheme with circuit breaker 2 having a similar circuit. This is the simplest application of the tripping scheme and uses an under-reaching relay at each end terminal.

A guard signal is transmitted continuously from each terminal, energizing guard relays of the two receivers of 85-1 & 85-2 and opening their contacts in the associated breaker trip circuits. If a fault occurs within the reach setting of the directional under-reaching relay (21-1), it will trip circuit breaker 1 directly. This relay is set the same as a zone 1 instantaneous relay. In addition, 21-1 shifts the transmitted signal from guard frequency to trip frequency.

If the fault occurs beyond the reach of 21-1, but within the reach of 21-2, that relay shifts to the trip frequency. A trip occurs when the guard relay contact, (85G1) drops out and the trip relay contact (85T1) closes. Each terminal receives only the signal from the remote transmitter.

The frequencies of this equipment are selected so that there is no interaction between channels. However, this scheme is not secure because a trip can occur simply by having the receiver relays tripping contact close. This can happen inadvertently during maintenance or calibration or it can be caused by electrical noise accompanying switching in the substation or by control circuit transmitting during relay operations. The frequencies are usually selected so that, in normal operation, the receiver will see the guard frequency, allowing its contact to open before it sees a trip frequency when its contact closes.

However, in the presence of random noise, this cannot always be relied upon. Therefore, two transmitter/receiver sets are some times used to prevent a false trip, as shown in Fig. 4.3-6. These receivers operate on two different frequencies and tripping requires both receivers to operate. Security is improved since it is very unlikely that the two frequencies would be present, simultaneously by accident. There is, however,

a decrease in dependability with this solution since there are twice as many components involved. In addition, the cost is greater for both capital and maintenance. The relay 21-1, in Fig. 3-4 & 3-5 represents both phase and ground directional high speed, first zone devices that are set to overlap each other but not to reach beyond the remote terminal. For a fault in this zone between A and B, the under-reaching relays at both ends of the line operate and trip their respective breakers directly. At the same time trip signals are sent from both terminals. Receipt of these signals will energize the trip coils of both breakers and trip them, if they have not already been tripped directly by their respective under-reaching relays. If overlapping settings are not possible, such as in any short lines where an under-reaching relay cannot be set reliably to distinguish between an end-of-line fault and an external fault, this scheme cannot be used.

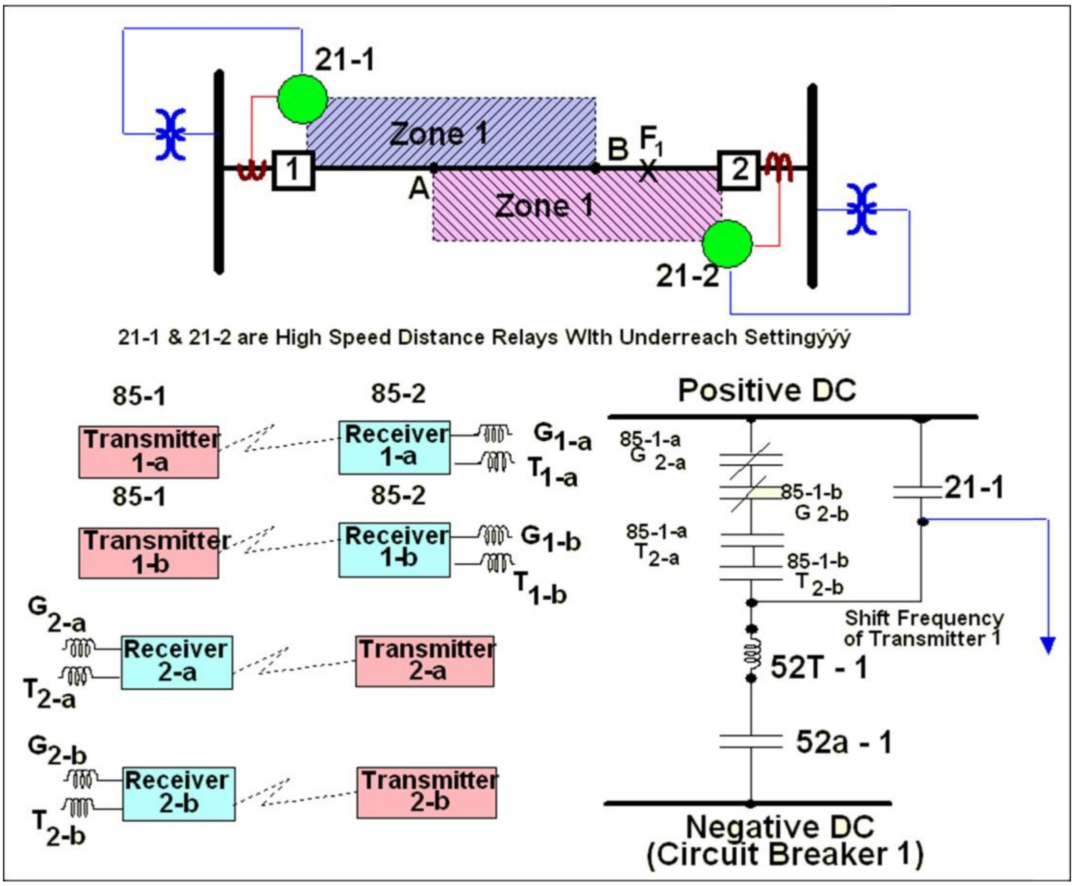


Fig. 4.3-6 Direct Under-Reaching Transfer Trip With Dual Transmitter-Receiver Sets

PERMISSIVE OVER-REACHING TRANSFER TRIP

A more common and less expensive, solution to increase the security of the DTT is to provide an over-reaching fault detector in a Permissive Over-Reaching Transfer Trip **(POTT)** scheme. This is somewhat similar to the Directional Comparison Blocking scheme in which the Directional Over-Reaching Relay serves as both the fault detector similar to the non-directional impedance relay in the blocking scheme and permissive interlock to prevent inadvertent trips due to noise. The received signal provides the tripping function. A trip signal instead of a blocking signal is used and each terminal is tuned to a different frequency and, therefore, can only respond to the remote transmitter signal. The settings can be "tighter" than in the directional comparison blocking scheme, where the over-reaching relay only has to see beyond the next bus section. There is no need to coordinate with a blocking relay of an adjacent line.

The phase and ground trip fault detectors at both terminals must be directional (looking into the line) and must operate for all internal faults.

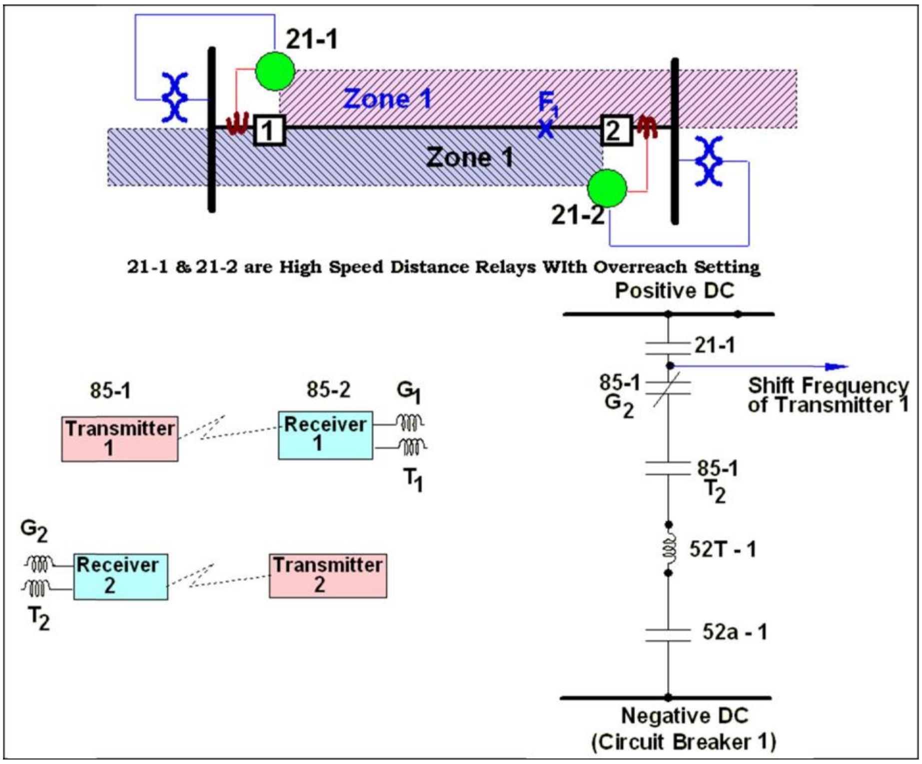


Fig. 4.3-7 Permissive Over-Reaching Transfer Trip

Over-Reaching Transfer-Trip systems provide highly secure transmission line protection. Both a trip signal from the remote terminal and the local fault detector operation are required for tripping. Dependability tends to be less than that of the blocking system, however, because transmission of a signal is required for tripping. Referring to Fig. 4.3-7(a), Directional Relays 21-1, and 21-2 send tripping signals to the remote ends. Since only an internal fault will cause both directional, over-reaching relays to operate, a trip occurs if the local over-reaching relay operates and a tripping signal is received. Tripping is now dependent on both a transmitted signal from the remote end, 85G1 dropping out and 85T1 picking up at the local terminal.

OVER-REACHING TRANSFER TRIP RECEIVER LOGIC

Fig. 4.3-7(b) shows the over-reaching transfer trip receiver logic. The blocking (guard) state exists under normal conditions with no output from trip state. An unblocking (trip) state exists when an internal fault occurs. In other words, there is no AND1 output under normal conditions. When the guard is shifted to trip on an internal fault, the absence of guard and the presence of trip signal activate the AND1 output, energizing receiver relay R.

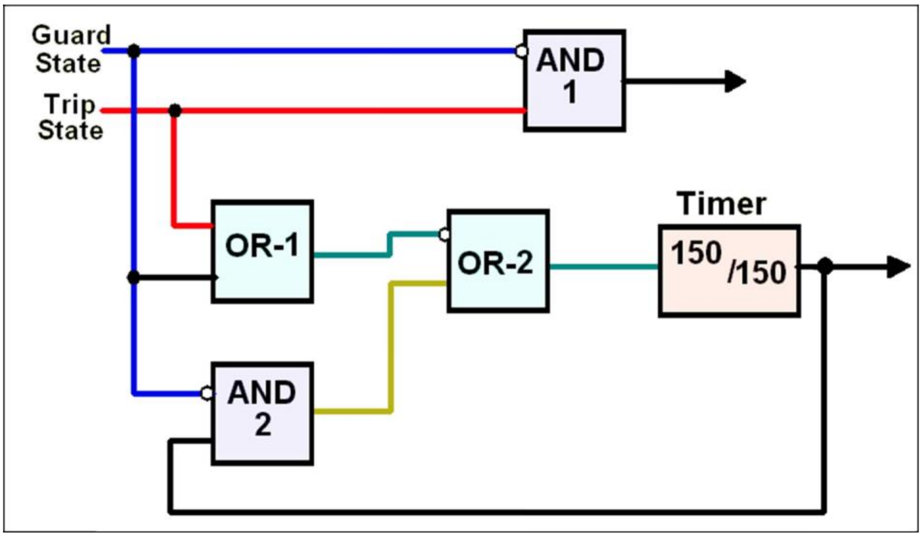


Fig. 4.3-7(b) Over-Reaching Transfer Trip Receiver Logic

An output from either the guard or trip to OR1 gate will not input to OR2. When the guard signal is absent, it initiates the Timer for lockout after 150 ms run out through OR1 and OR2 locking out the relaying and energizing the lockout alarm. The lockout

is maintained by the Timer output (Active High logic) through AND2, as long as there is no guard signal (No Guard Signal = Low logic). When the guard signal returns, the timer is de-energized and resets itself after 150 ms. This feature is known as Guard Return. Table 4.3-3 shows the operation of Over-Reaching Transfer-Trip System corresponding Fig. 4.3-7(a) and Fig. 4.3-7(b) for internal and external faults.

TYPE OF FAULT	EVENTS AT TERMINAL A	EVENTS AT TERMINAL B
Internal (F1)	D_{ab} operates. Transfer-Trip signal (f_l) keyed to station B. Transfer-Trip from station B (f_2) operates receiver Relay R. Breaker 1 trips.	Dba operates. Transfer-Trip signal (f_2) keyed to Terminal A. Transfer-trip (f_1) from Terminal A operates receiver Relay R. Breaker 2 trips.
External (F2)	Dab operates. Transfer-Trip signal (f_1) keyed to Terminal B. Transfer-Trip signal (f_2) not received from Terminal B. No trip occurs.	Dba does not see fault. Transfer-trip (f_1) from Terminal A operates receiver Relay R. No trip occurs.

Table 4.3-3 Operation of Over-Reaching Transfer-Trip System

PERMISSIVE UNDER-REACHING TRANSFER TRIP

The use of two relays, an under-reaching and an over-reaching relay, at each terminal, as shown in Fig. 4.3-8, result in even greater security. The under-reaching relays, 21-1U and 21-2U, initiate the trip by shifting the transmitted frequency from guard to trip and the over-reaching relays, 21-1O and 21-2O, provide the permissive supervision. In addition, the under-reaching relays can provide a Zone 1, instantaneous direct tripping function to local breakers and the over-reaching relays with an added timer, can provide backup second Zone protection. Again each terminal only receives the remote transmitter signal.

The advantage of Permissive Under-Reaching over the Permissive Over-Reaching Transfer Trip scheme is the availability of the two relays for backup protection.

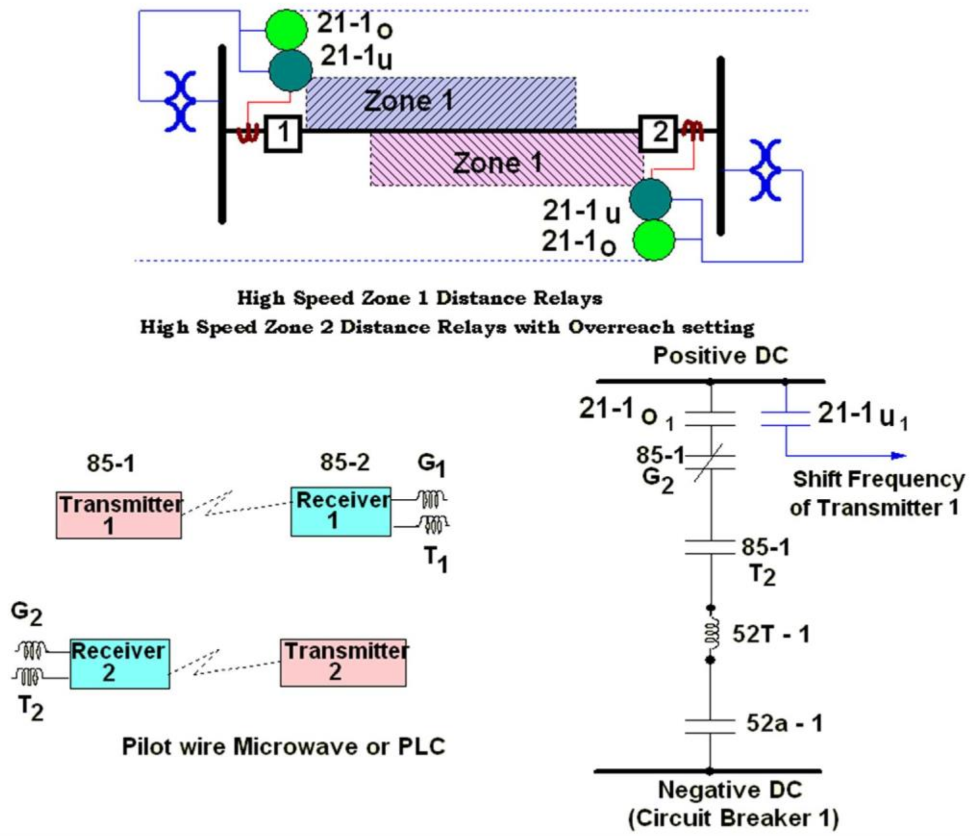


Fig. 4.3-8 Permissive Underreaching Transfer Trip

Table 4.3-4 shows the operation of Permissive Under-Reaching Transfer-Trip System corresponding Fig. 4.3-8 for internal and external faults.

TYPE OF FAULT	EVENTS AT TERMINAL A	EVENTS AT TERMINAL B
Internal (F1) near Terminal B	D_{ab} does not operate. No Transfer-Trip signal (fl) sent to station B. FD_{ab} operates Transfer-Trip (f_2) from station B operates receiver Relay R., Breaker 1 trips.	D_{ba} operates and trips directly. Transfer-Trip signal (f2) keyed to Terminal A. FD_{ba} operates receiver Relay R. Breaker 2 trips.
External (F2)	D_{ab} does not operate. No Transfer-Trip signal (f1) sent to Terminal B. No trip occurs.	D_{ba} does not operate. No Transfer-trip (f2) to Terminal A. No trip occurs.

Table 4.3-4 Operation of Under-Reaching Transfer-Trip System

PILOT WIRE RELAYING

Pilot wire relaying is used where the distance between each end of the line is quite short, say up to 10 miles. For short lines we could consider differential protection, as shown in Fig. 4.3-9. The CTs at each end of the line are interconnected by pilot wires. Employing the well known differential principle, this would compare the current entering the line with the current leaving.

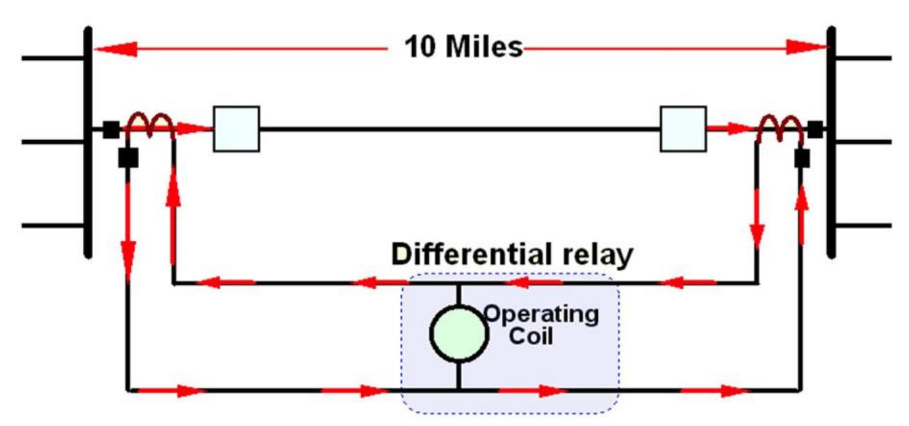


Fig. 4.3-9 Differential Principle

In practice, it is usual to install a separate relay at each end of the line interconnected by a pilot wire, as shown in Fig. 4.3-10. The relays are fitted with restraining coils, which try to hold the operating contactors open, while the operating coils try to close them, respectively, at both ends.

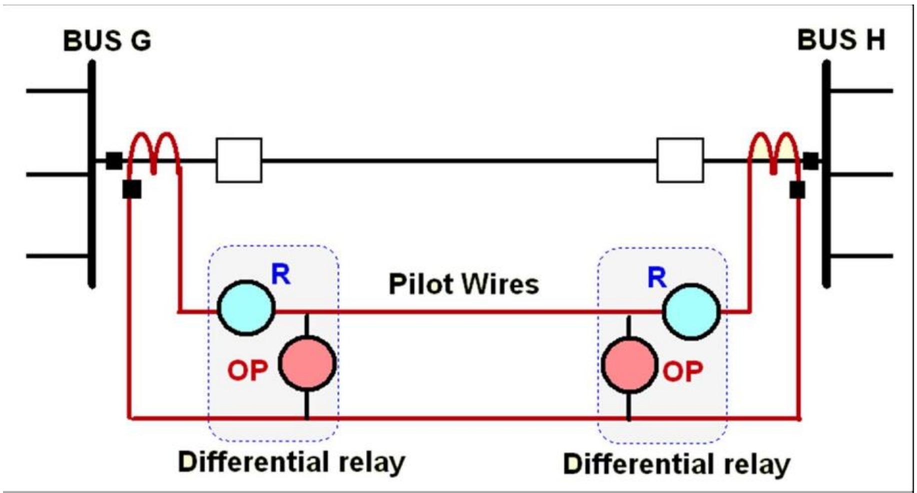


Fig. 4.3-10 Pilot Wire Differential Protection

When there is an external fault, the current in the CT secondaries circulates through the restraining coils. In this situation, the relays will not trip their respective breakers. This is true for a through fault. Note that the presence of circulating current through the pilot wires blocks tripping. In the case of a fault within the protected line, the current will feed in from both ends. Now we have a large secondary current flowing through the operating coil, but little or no current circulating through the pilot wires and restraint coils. Both relays will operate to trip the breakers at each end of the line, resulting in rapid clearing of the fault. Fig. 4.3-11 shows another arrangement, called the opposed voltage principle. Note that the position of the operating and restraining coils are now reversed. The main feature of this system is that an internal fault causes current to flow in the pilot wires and energize the operating coils to “trip”. This is the opposite to the circulating current principle.

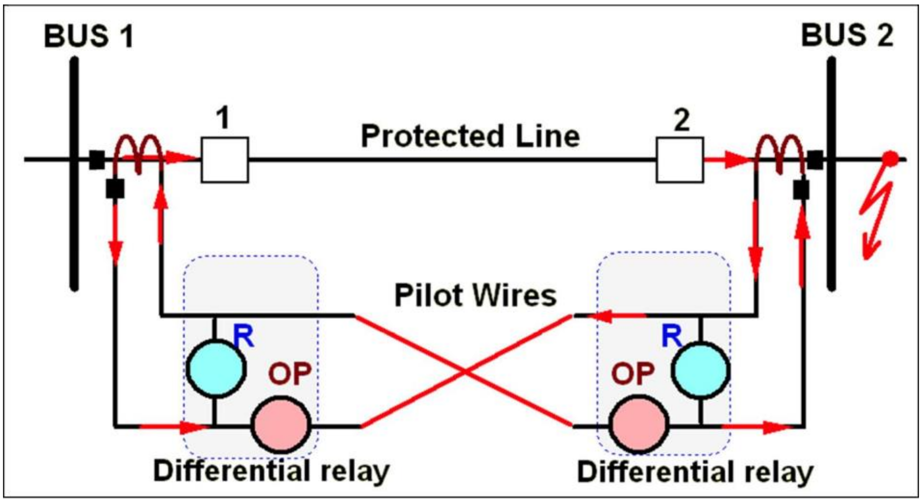


Fig. 4.3-11 Opposed Voltage Pilot Wire Relaying (Through-Current Condition)

Fig. 4.3-12 shows a typical arrangement, which is commonly used on pilot wire schemes. At each end of the line, CTs are connected to each phase and these are fed into a common sequence filter. This filter actually measures and converts three phase currents into a single phase output, which represents both positive and zero sequence components. Polarity and the phase angle of the voltage depends upon the direction of primary current flow through the CTs.

This output is fed into a saturating transformer. The purpose of this is to limit the voltage output to about 15 volts no matter what type of fault is involved. This voltage

produces a current flow through the relay and along the pilot wires to the equipment at the other end. Usually the pilot wires are isolated from the relay circuit and the CT secondary circuit by an isolating transformer.

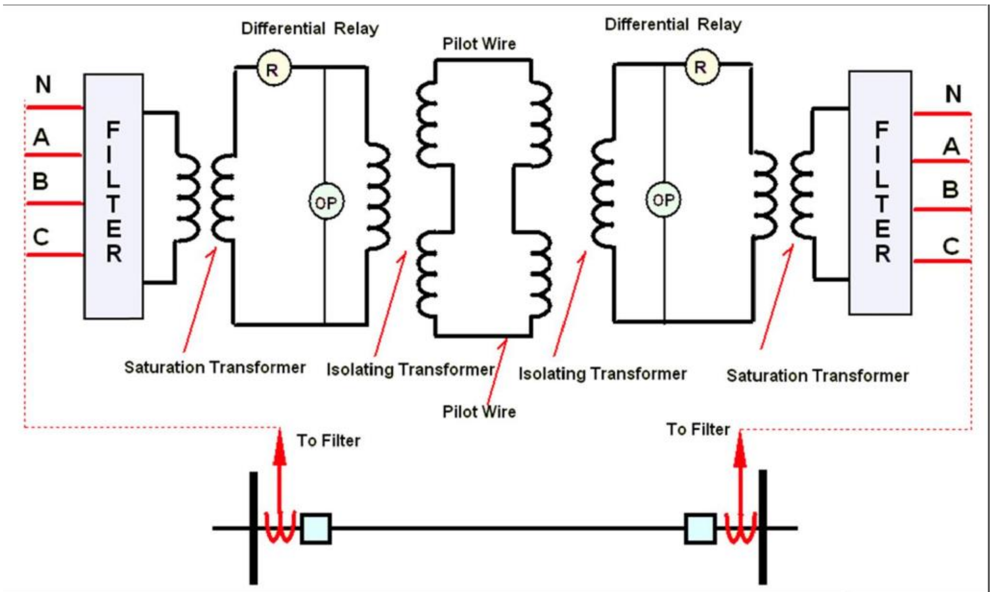


Fig. 4.3-12 Typical Pilot Wire Scheme (Phase Comparison)

Where the fault is external, that is a through fault, the sequence filter at the far end will produce a terminal voltage, which is of the opposite polarity. So, the current circulates around the pilot wire circuit and through the restraint coils, but not through the relay operating coils.

For a fault within the transmission line, the voltage produced by the far end sequence filter will be of the same polarity. Therefore, current will flow through the operating coil of both relays and trip both breakers. This system is known as Phase Comparison, utilizing pilot wire protection.

If the pilot wires became open circuited, an external fault would cause both relays to operate. A short circuit between the two pilot wires would effectively short-out the operating coils of both relays and hence block tripping. In the case of a transmission line fault, internal or external, all of the secondary current would flow through the restraint coils and so make the relays ineffective.

The fault would not be cleared. Often a monitoring system is installed in order to detect open or short circuits in the pilot wires.

A DC **m**illiamp **s**ignal is in**j**ected into the pilot **w**ire circui**t**, as show**n** in Fig. 4.3-13. If the D**C** signal **i**s interru**p**ted, an **a**larm is i**n**itiated. **A**nother m**o**nitoring scheme measu**r**es curren**t** circulating in diffe**r**ent parts **o**f the circ**u**it, as show**n** in Fig. 4.3-14. The t**wo** conduct**o**rs are al**w**ays twiste**d** together to form a **p**air becau**s**e this red**u**ces the interfe**r**ence due to inducta**n**ce from **n**earby sig**n**als and e**x**ternal vo**l**tages suc**h** as the power line itself.

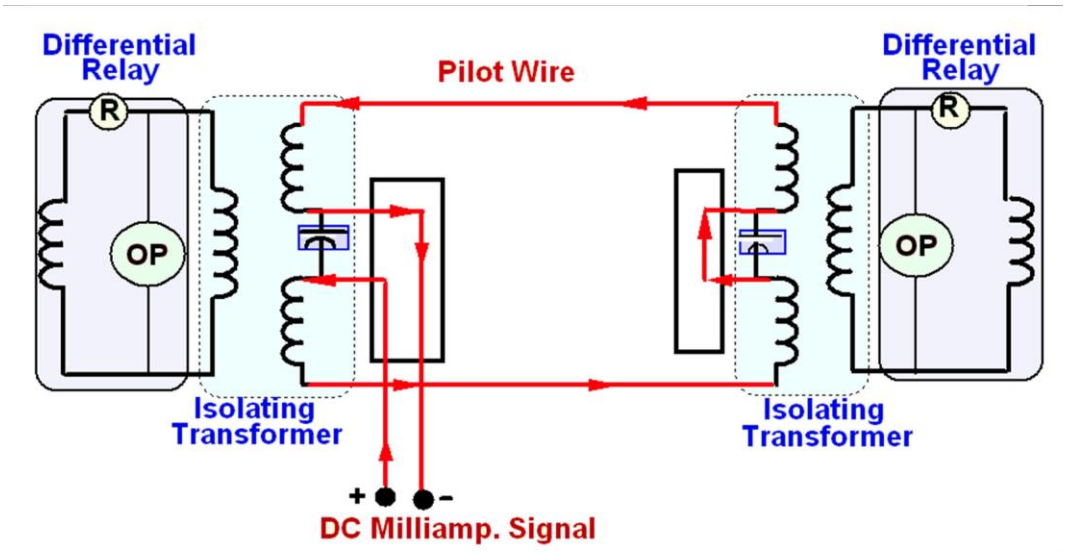
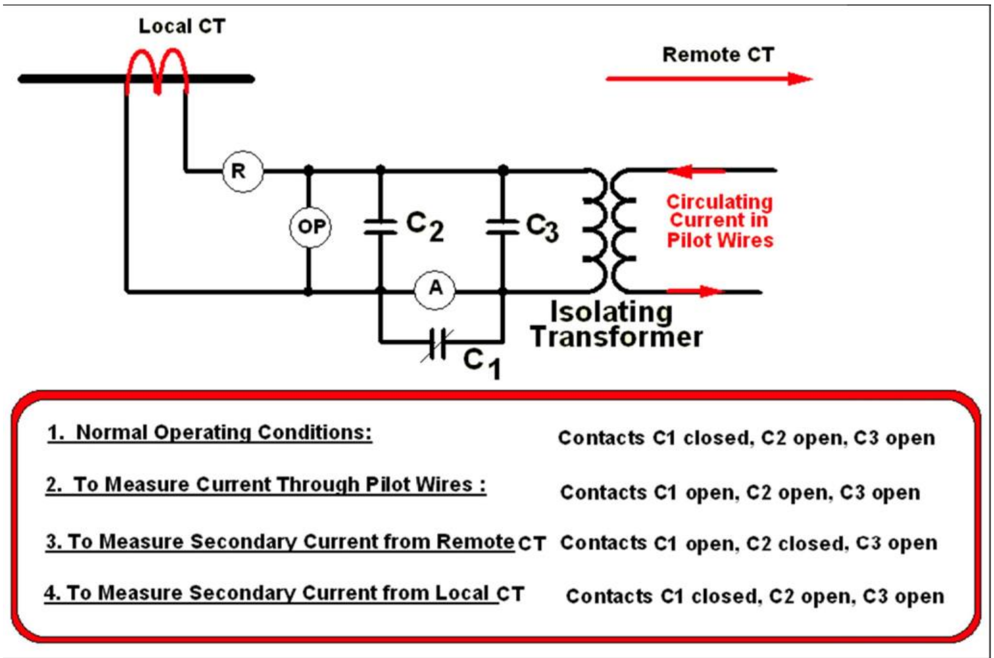


Fig. **4**.3-13 Pil**o**t Wire M**o**nitoring S**y**stem



Fi**g**. 4.3-14 **P**ilot Wire **T**est Circuit Functio**n**al Schem**a**tic

Even a small induced voltage in the pilot wires may be sufficient to cause mal operation of the protection relays. Therefore, it is usual to provide a mutual drainage reactor at each end of the line, which will effectively discharge the high voltage to ground.

A typical system uses a gas discharge tube, as shown in Fig. 4.3-15. The reactors add equal impedance to the drainage circuit and insure that both conductors flashover, simultaneously. Otherwise the voltage difference could cause operation of the relays and unnecessary tripping of breakers. The flashover voltage is about 500 volts. The drainage reactor must be grounded to the surrounding earth instead of the sub-station ground mat.

The earth is commonly known as remote ground to distinguish it from the station ground mat. A voltage difference can arise between these two grounds if a ground fault occurs on the power line. As fault current flows through the earth, the ground resistance and the resistance of the station ground produces a voltage drop raising the potential of the station ground mat. The difference in voltage between the ground mat and the pilot wire shielding could cause the large fault current, from the power line, to flow along the shield and cause damage to the cable.

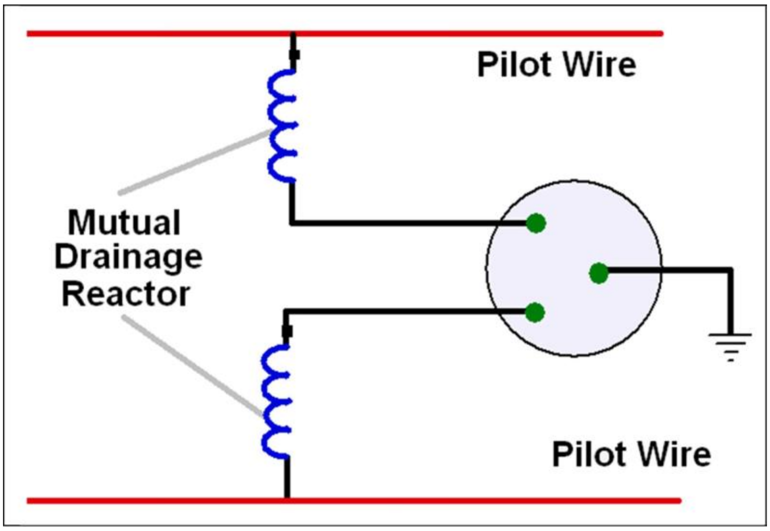


Fig. 4.3-15 Mutual Drainage Reactor installed at each end of Pilot Wire

For this reason, the shielding is terminated outside of the ground mat area. The drainage reactors are grounded in a similar manner. However, we still have a problem.

When the two pilot wire conductors enter the station, they will be connected to relays, which are usually grounded to the mat on one side, so that one of the pairs may be subjected to raising ground mat potential. The difference in voltage between the two conductors may cause inadvertent tripping of the relays. This problem is resolved by installing a Neutralizing Transformer, as shown in Fig. 4.3-16. This raises the voltage of both conductors to compensate for the difference. The primary of the neutralizing transformer is connected between the station ground mat and the remote earth, registering the difference in potential. This usually occurs only when a ground fault exists on the power line. The neutralizing transformer has two secondaries each of which are connected in series with each conductor of the twisted pilot pair. Now, as the voltage across the primary rises, it superimposes the same voltage on both conductors. When you are working around this equipment in the field, always remember that the remote earth may be at different potential from the station ground. Be careful not to place yourself across these two potentials.

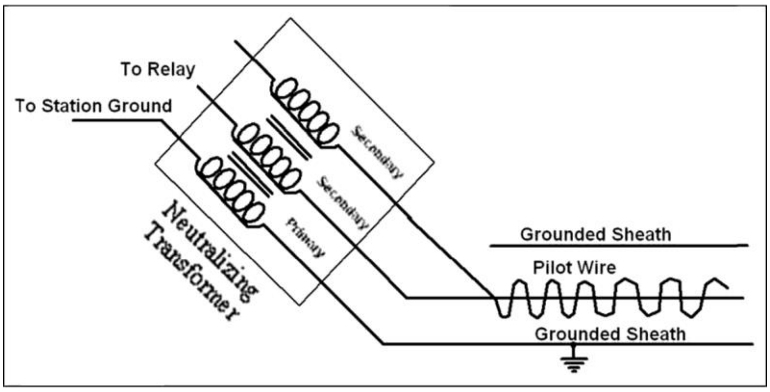


Fig. 4.3-16 Neutralizing Transformer

In many installations, DC polarized relays are used because of their high sensitivity and high speed. In this arrangement, the circulating current is rectified in two separate units and the resultant DC passed to the operating coil and the restraint coil, as shown in Fig. 4.3-17. These two coils are wound in opposing directions on the same core/armature, which moves within the field of a permanent magnet, as shown in Fig. 4.3-18. When the flux from the operating coil is greater than that from the restraint coil, the armature will move, closing the tripping contacts.

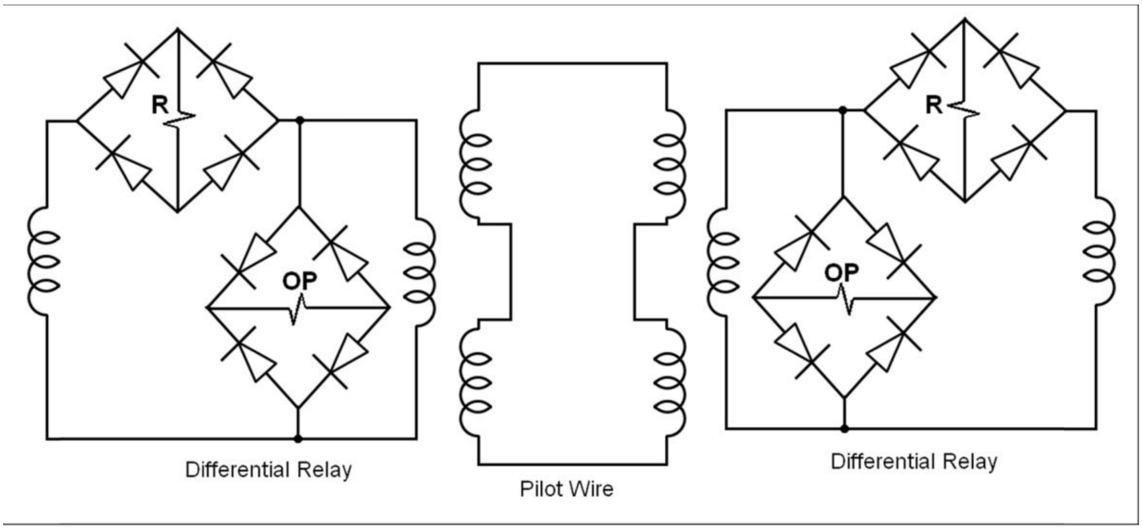


Fig. 4.3-17 Rectifying Restraining and Operating Currents for Polar Unit

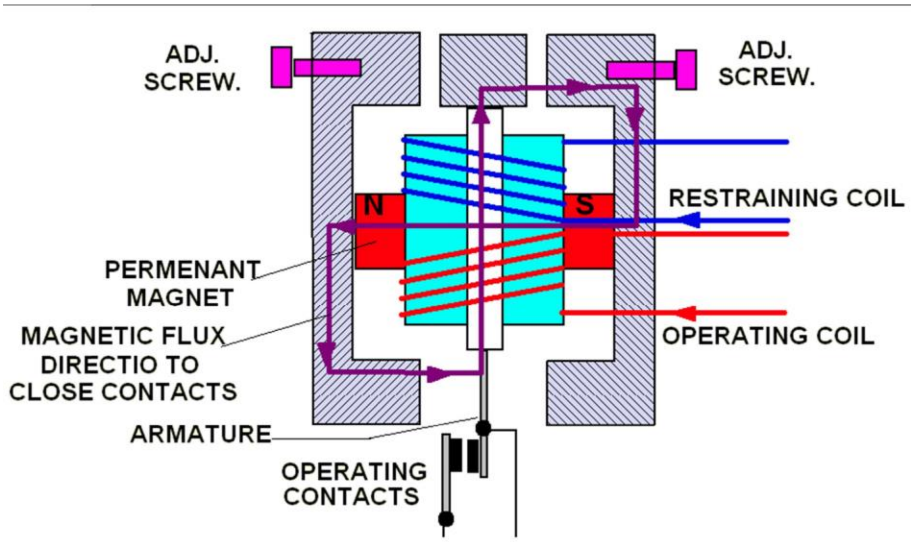


Fig. 4.3-18 DC Polarized Unit

SUMMARY

It is not possible to clear a fault from both ends of a transmission line, instantaneously, if the fault is near one end of the transmission line.

There is always an uncertainty at the limits of protective zone.

Pilot Wire protection is more practical and economical for distances less than **5-10 miles**.

The four types of communication channels used between each end of the transmission line, are:- Solid metallic connection - Pilot Wire (Communication

Cable), Power Line Carrier **(PLC)**, Microwave, Fiber Optic Cable and Radio Frequency (Mobile Radio).

- A blocking mode is one in which the presence of a transmitted signal prevent tripping of a circuit breaker.
- In Extra High Voltage **(EHV)** systems, two primary and secondary protection schemes may be used, where one may be operating in tripping mode and the other in blocking mode providing protection diversity.
- A directional relay can differentiate between internal or external fault.
- A directional relay, usually an Admittance type **(Mho)** or Quadrilateral Relay, is used to inhibit the transmitter, for blocking signal.
- The blocking signal in the directional comparison scheme is transmitted only when a fault occurs.
- A low energy continuous carrier blocking (guard) signal is transmitted as a supervisory check on the communication link during normal operation.
- In the blocking scheme, the blocking relay must be more sensitive than the tripping relay.
- Using two Directional Relays, under-reaching and over-reaching relay at each terminal result in greater system security.
- The **advantage** of Permissive Under-Reaching over the Permissive Over-Reaching Transfer Trip scheme is the availability of the two relays for backup protection.
- Small induced voltages in the pilot wires may cause misoperation of the protection relays.
- The reactors add equal impedance to the drainage circuit and insure that both conductors flashover, simultaneously.
- The earth is commonly known as **remote ground** to distinguish it from the **station ground** mat.

GLOSSARY

Pilot Wire/Tele-Protection:	A communication channel between two or more ends of a transmission line to provide instantaneous clearing over 100% of the line
PLC:	Power Line Carrier
EHV:	Extra High Voltage
DUTT:	Direct Under-Reaching Transfer Trip
DOTT:	Direct Over-Reaching Transfer Trip
POTT:	Permissive Over-Reaching Transfer Trip
PUTT:	Permissive Under-Reaching Transfer Trip
Bristle brush:	Of Hair
Charred:	Burnt
Proximity:	Closeness
Prevailing:	Existing
Viable:	Practical, Possible
Vulnerable:	Sinsable can be damaged
Pronged:	Thin sharp pointed

REVIEW EXERCISE

ANSWER THE FOLLOWING QUESTIONS

1. What is the main reason of using pilot wire protection?

2. List the reasons for pilot wire differential protection not being practical for the majority of transmission lines with long distance involved:

Choose the correct word to fill in the blank:

3. Pilot wire relaying is used where the line length is **(long; short)**, say up to about ________ miles.

4. The term __________________ refers to a communication channel between two or more ends of a transmission line to provide instantaneous clearing over 100% of the line.

5. List the five types of communication channels used between each end of the transmission line:
   i) ____________________________
   ii) ____________________________
   iii) ____________________________
   iv) ____________________________
   v) ____________________________

6. List the factors controlling the selection of a communication channel for the protection of a transmission line:

SELECT TRUE OR FALSE OF THE FOLLOWING:

7. A blocking mode is one in which the presence of a transmitted signal initiates tripping of a circuit breaker. a) True b) **F**alse
8. The blocking signal in the directional comparison scheme is transmitted only when a fault occurs. c) True d) **F**alse

9. With the directional Comparison Blocking scheme, a failure of communication link will cause a false trip to occur during an external fault. a) True b) **F**alse

10. Given Fig. 4.3-4 for Directional Comparison Unblocking scheme, during an internal fault, the tripping relay **(D)** at each end causes the transmitter to shift to the unblocking frequency, providing an input to OR2 and then to the receiver relay R, allowing the circuit breaker to trip. a) True b) **F**alse

11. In the Directional Comparison-Blocking or Unblocking Schemes, if the carrier goes off during a fault, both schemes may cause false trips. a) True b) **F**alse

12. Given Fig. 4.3-19 for Directional Comparison Unblocking scheme, under normal conditions, a blocking signal **(Hi logic)** is sent continuously to inhibit the OR1 gate output and as a result, AND1 and AND2 receive valid inputs **(Hi logic)** through path (a).

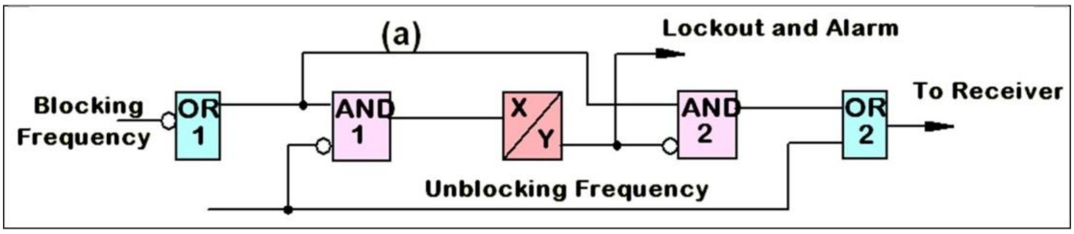


Fig. 4.3-19 Directional Comparison Unblocking Scheme

a) True **b**) False

13. As shown in Fig. 4.3-2**0**, two tra**n**smitter/receiver set**s** are used to preven**t** a false tri**p**ping, but **r**equires both receive**r**s to opera**t**e on two __________ frequencies.

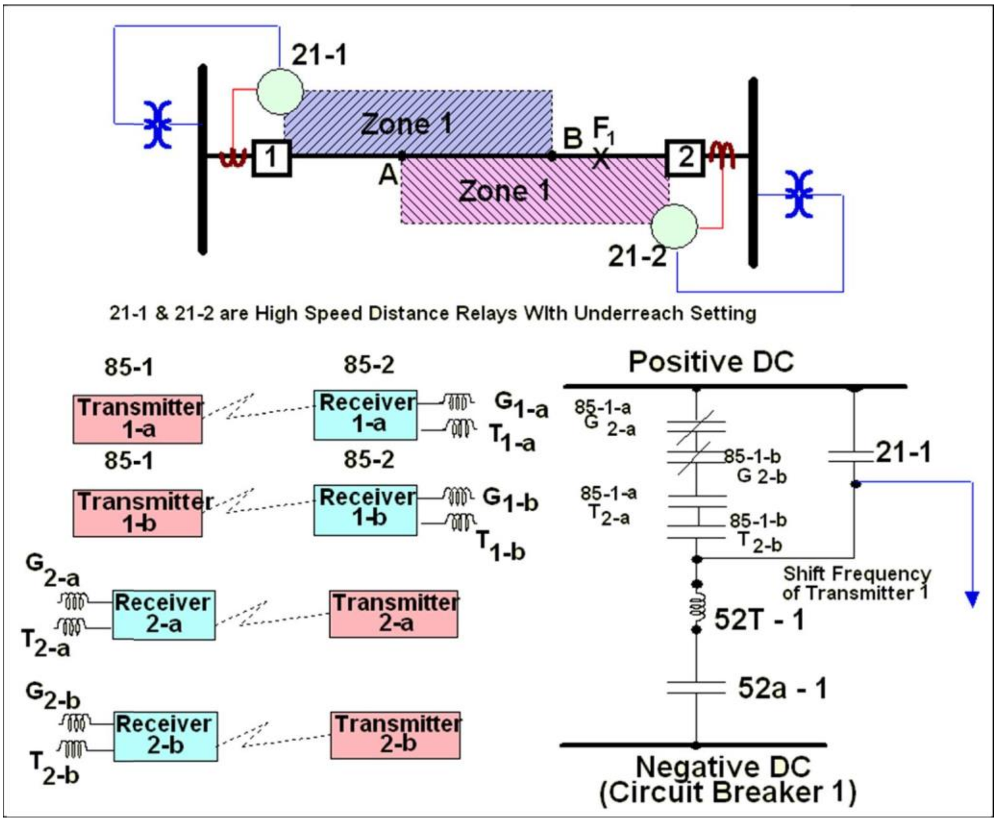


Fig. **4**.3-20 Dir**e**ct Under-Reaching **T**ransfer **T**rip, With **D**ual Tran**s**mitter-Re**c**eiver Sets

14. In **F**ig. 4.3-21 for Permissive Ove**r**-Reachin**g** Transfer **T**rip, direc**t**ional rela**y**s 21-1, an**d** 21-2 sen**d** tripping signals to the ______________ , trippin**g** being de**p**endent on both a tra**n**smitted signal fro**m** the rem**o**te end 85**G**1 __________________ and 85**T**1 _____________ a**t** the local **t**erminal.

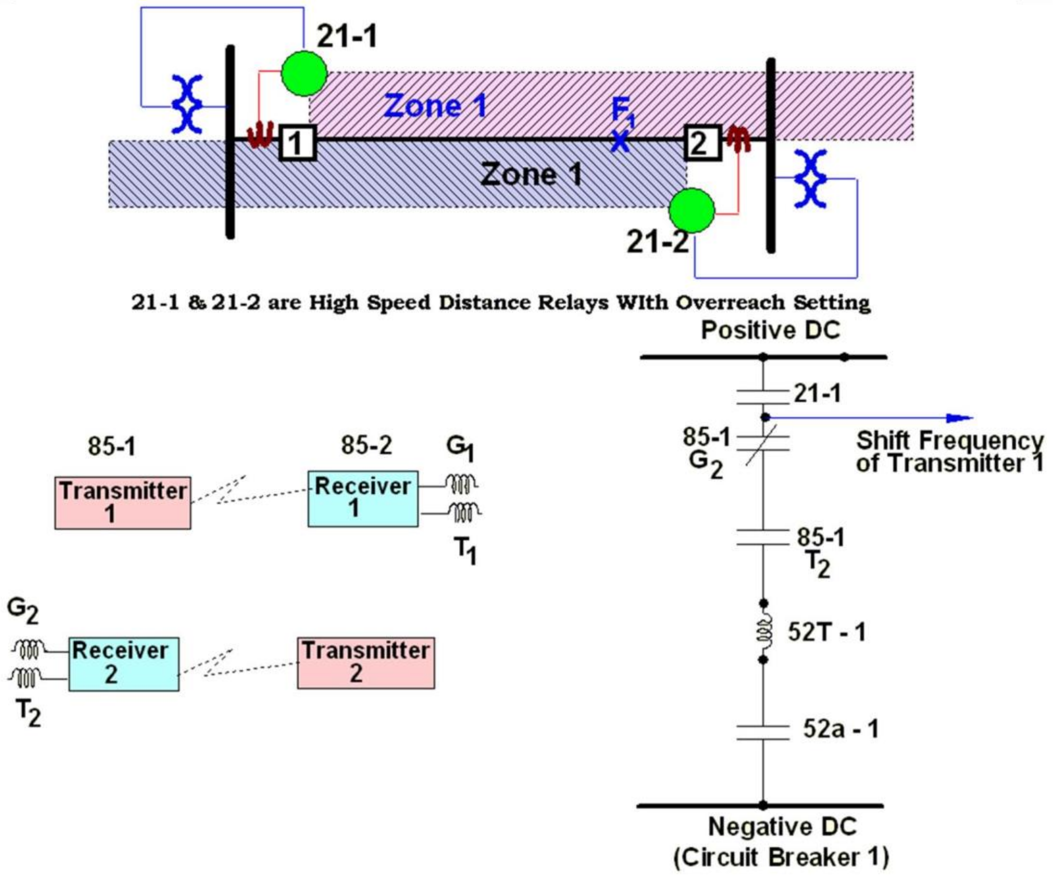


Fig. 4.3-21 Permissive Over-Reaching Transfer Trip

15. The advantage of permissive under-reaching over the permissive over-reaching transfer trip scheme is ____ .

16. In Fig. 4.3-22 for Permissive Under-Reaching Transfer Trip, the under-reaching relays, 21-1U and 21-2U, initiate the trip by shifting the transmitted frequency from   to   and the over-reaching relays, 21-1O and 21-2O, provide

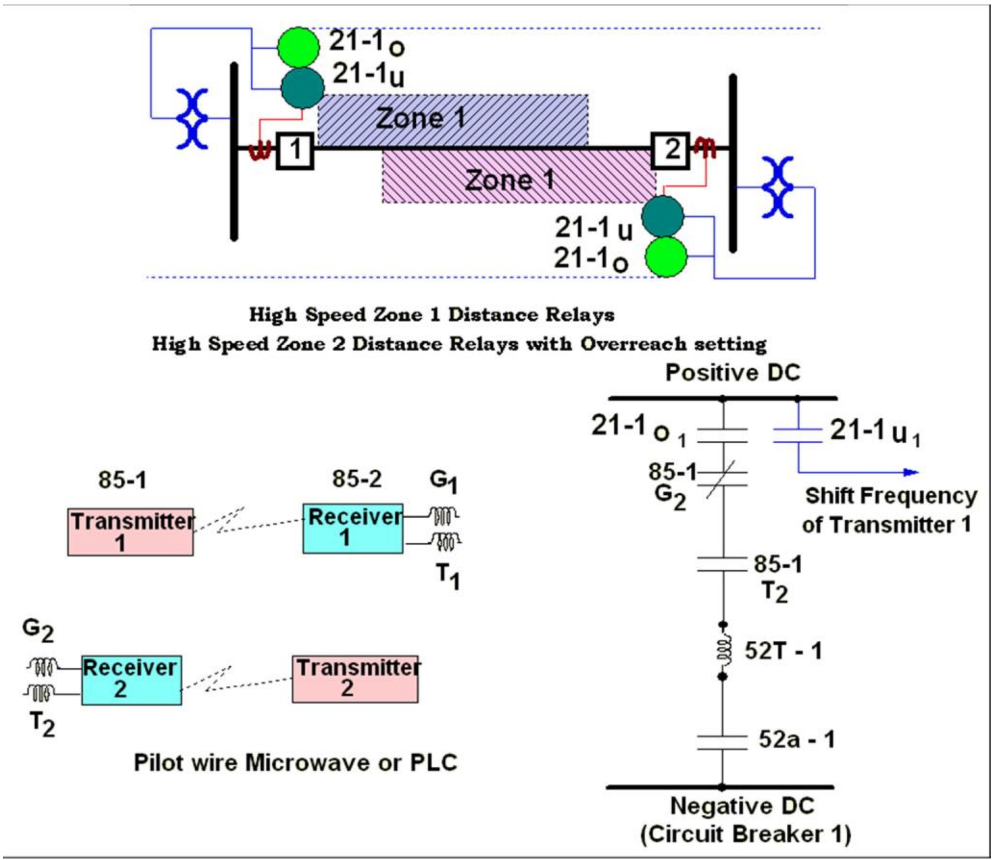


Fig. 4.3-22 Permissive Under-Reaching Transfer Trip

17. Identify the basic protection scheme used for a short transmission line of 10 miles length, as shown in Fig. 4.3-23.

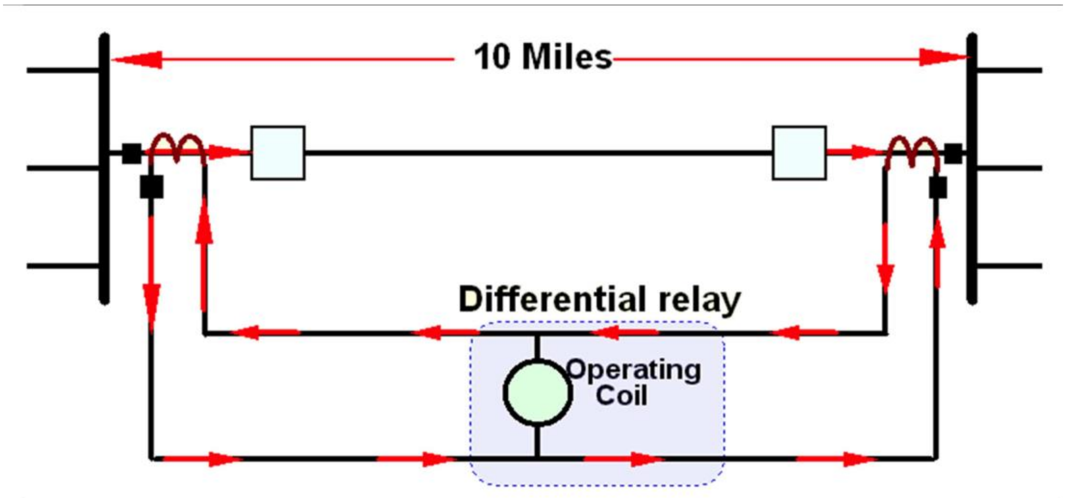


Fig. 4.3-23

18. In Fig. 4.3-24 with an internal fault, circulating current flows in the pilot wires.

a) True b) False

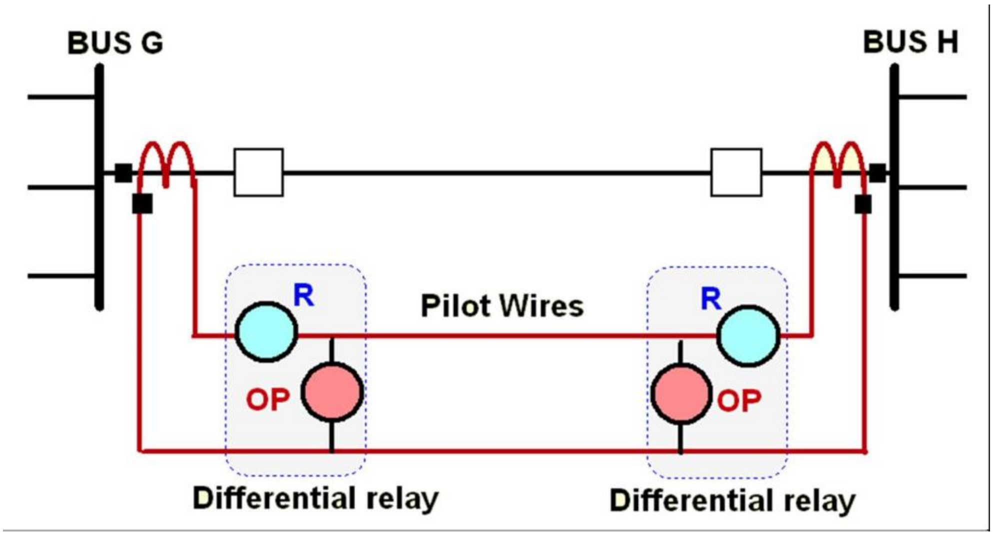


Fig. 4.3-24 Pilot Wire Differential Protection

19. In Fig. 4.3-24 for Pilot Wire Protection against an internal fault, the Restraining coils **(R)** try to hold the operating contacts _____________, while the Operating coils **(OP)** try to _____________ them, at both ends.

20. Identify the basic protection scheme used for a short transmission line of 10 miles length, as shown in Fig. 4.3-25.

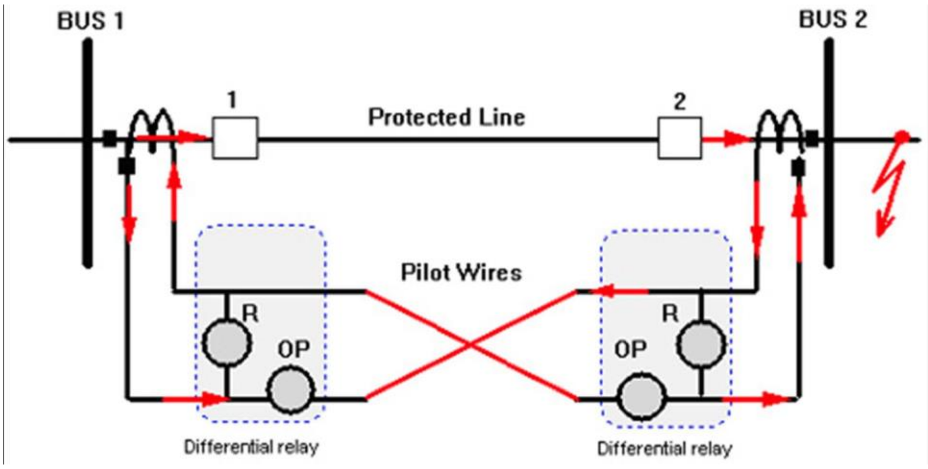


Fig. 4.3-25

21. In Fig. 4.3-26, polarity and phase angle of the voltage output of the filter is determined by the direction of the primary current flow in the CTs.

a) True b) False

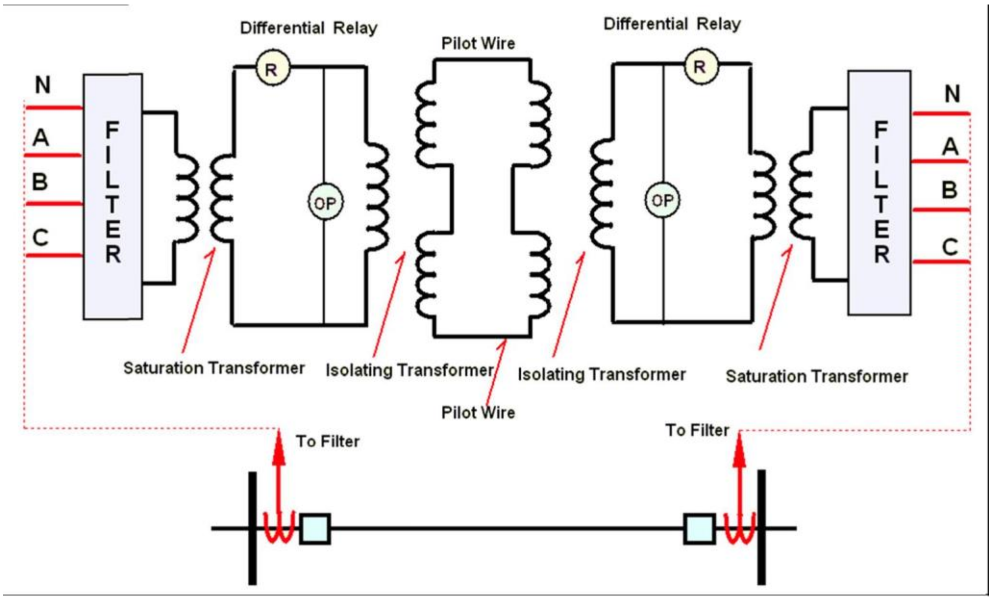


Fig. 4.3-26 Typical Pilot Wire Scheme (Phase Comparison)

22. In Fig. 4.3-26 for Pilot Wire protection scheme by phase comparison, a short circuit between the two pilot wires would effectively short-out the __ coils of both relays and hence block ______________________________ .

23. What is the purpose of the saturating transformer in Fig. 4.3-26?

24. What is the purpose of the sequence filter in Fig. 4.3-26?

25. Why is the Pilot Wire protection scheme in Fig. 4.3-26 known as “phase comparison”?

26. Small voltages induced in the pilot wires can cause misoperation of the relays. How is this prevented? Draw a sketch.